

Appendix D

OVERVIEW OF U.S. SEISMICITY

INTRODUCTION

The U.S. Geological Survey (USGS), together with the National Science Foundation (NSF), conducts and sponsors the major national effort in earthquake-related studies in seismology, geology, and geophysics. At present, the USGS has identified nine geographic areas in the United States as priority study areas: the intermountain seismic belt including the Wasatch Front of Utah; Puget Sound, Washington; Alaska; southern California; Hawaii; the central Mississippi valley; the southeastern United States including Charleston, South Carolina; the northeastern United States including Massachusetts and New York; and Puerto Rico and the Virgin Islands. A considerable amount of data on the earthquake hazard in these areas is available from the USGS and ongoing studies are continually adding to the store of information. When integrated with geologic data, studies of seismicity provide answers to the questions *where, how big, how often, and why* earthquakes occur. The information on U.S. seismicity included here is based on ongoing research by the USGS National Earthquake Information Center. It is presented to alert the reader to the national nature of the seismic hazard. Detailed information about specific areas can be obtained from geologists, geophysicists, and seismologists affiliated with area academic institutions; regional offices of the USGS and FEMA; national earthquake information centers; and state and regional seismic safety organizations.

The Modified Mercalli intensity scale (MMI) is used in the seismicity information presented here as the reference when instrumental data to define Richter and surface wave magnitudes were unavailable. See Appendix A for a brief explanation of these terms.

NORTHEAST REGION

The record of earthquakes in the United States (and the Northeast) is believed to have started with the Rhode Island earthquake of 1568. Including earthquakes originating in the St. Lawrence River Valley in Canada, 16 important earthquakes have occurred in the northeast region since 1568.

Important Earthquakes of Eastern Canada and New England

Date	Location	Maximum MMI (I_0)	Magnitude (Approx. M_s)
1534-1535	St. Lawrence Valley	IX-X	
June 11, 1638	St. Lawrence Valley	IX	
Feb. 5, 1663	Charlevoix zone	X	7.0
Nov. 10, 1727	New Newbury, MA	VIII	7.0
Sept. 16, 1732	Near Montreal	VIII	
Nov. 18, 1755	Near Cape Ann, MA	VIII	
May 16, 1791	East Haddam, CT	VIII	
Oct. 5, 1817	Woburn, MA	VII-VIII	
Oct. 17, 1860	Charlevoix zone	VIII-IX	6.0
Oct. 20, 1870	Charlevoix zone	IX	6.5
Mar. 1, 1925	Charlevoix zone	IX	7.0
Aug. 12, 1929	Attica, NY	VIII	5.5
Nov. 18, 1929	Grand Banks of Newfoundland	X	8.0
Nov. 1, 1935	Timiskaming, Quebec	VIII	6.0
Sept. 5, 1944	Massena, NY; Cornwall, Ont.	VIII	6.0
Jan. 9, 1982	North Central New Brunswick	V	5.7 (m_b)

SOUTHEAST REGION

The southeastern United States is an area of diffuse, low-level seismicity. It has not experienced an earthquake having an MMI of VIII or greater in nearly 80 years. The largest and most destructive earthquake in the region was the 1886 Charleston earthquake which caused 60 deaths and widespread damage to buildings. It had an epicentral intensity of X and a magnitude (M_S) of approximately 7.7.

Important Earthquakes of the Southeast Region

Date	Location	Maximum MMI (I_o)	Magnitude (Approx. M_S)
Feb. 21, 1774	Eastern VA	VII	
Feb. 10, 1874	McDowell County, NC	V-VII	
Dec. 22, 1875	Arvon, VA area	VII	
Aug. 31, 1886	Near Charleston, SC	X	7.7
Oct. 22, 1886	Near Charleston, SC	VII	
May 31, 1897	Giles County, VA	VIII	6.3
Jan. 27, 1905	Gadsden, AL	VII-VIII	
June 12, 1912	Summerville, SC	VI-VII	
Jan. 1, 1913	Union County, SC	VII-VIII	5.7-6.3
Mar. 28, 1913	Near Knoxville, TN	VII	
Feb. 21, 1916	Near Asheville, TN	VI-VII	
Oct. 18, 1916	Northeastern AL	VII	
July 8, 1926	Mitchell County, NC	VI-VII	
Nov. 2, 1928	Western NC		

CENTRAL REGION

The seismicity of the central region is dominated by the four great earthquakes that occurred in 1811-1812 near New Madrid, Missouri. These earthquakes had magnitudes (M_S) ranging from 8.4 to 8.7 and epicentral intensities ranging from X to XII. Some 15 of the thousands of aftershocks that followed had magnitudes greater than 6.

Important Earthquakes of the Central Region Through 1980

Date	Location	Maximum MMI (I_0)	Magnitude (Approx. M_S)
Dec. 16, 1811	New Madrid, MO	XI	8.6
Jan. 23, 1812	New Madrid, MO	X-XI	8.4
Feb. 7, 1812	New Madrid, MO	XI-XII	8.7
June 9, 1838	Southern IL	VIII	5.7
Jan. 5, 1843	Near Memphis, TN	VIII	6.0
Apr. 24, 1867	Near Manhattan, KS	VII	5.3
Oct. 22, 1882	West Texas	VII-VIII	5.5
Oct. 31, 1895	Near Charleston, MO	VIII-IX	6.2
Jan. 8, 1906	Near Manhattan, KS	VI-VIII	5.5
Mar. 9, 1937	Near Anna, OH	VIII	5.3
Nov. 9, 1968	Southern IL	VII	5.5
July 27, 1980	Near Sharpsburg, KY	VI	5.1

WESTERN MOUNTAIN REGION

A number of important earthquakes have occurred in the western mountain region. These include earthquakes in the Yellowstone Park-Hebgen Lake area in western Montana, in the vicinity of the Utah-Idaho border, and sporadically along the Wasatch front in Utah. The largest earthquake in the western mountain region in historic times was the 1959 Yellowstone Park-Hebgen Lake earthquake which had a magnitude (M_S) that is now believed to be in excess of 7.3. The strongest earthquake in 24 years occurred at Borah Peak in Idaho in October 1983; it had a magnitude of 7.3.

Important Earthquakes of the Western Mountain Region Through 1980

Date	Location	Maximum MMI (I_0)	Magnitude (Approx. M_S)
Nov. 9, 1852	Near Ft. Yuma, AZ	VIII?	
Nov. 10, 1884	Utah-Idaho border	VIII	
Nov. 14, 1901	About 50 km east of Milford, UT	VIII	
Nov. 17, 1902	Pine Valley, UT	VIII	
July 16, 1906	Socorro, NM	VIII	
Sept. 24, 1910	Northeast AZ	VIII	
Aug. 18, 1912	Near Williams, AZ	VIII	
Sept. 29, 1921	Elsinore, UT	VIII	
Sept. 30, 1921	Elsinore, UT	VIII	
June 28, 1925	Near Helena, MT	VIII	6.7
March 12, 1934	Hansel Valley, UT	VIII	6.6
March 12, 1934	Hansel Valley, UT	VIII	6.0
Oct. 19, 1935	Near Helena, MT	VIII	6.2
Oct. 31, 1935 (Aftershock)	Near Helena, MT	VIII	6.0
Nov. 23, 1947	Southwest MT	VIII	
Aug. 18, 1959	West Yellowstone-Hegben Lake	X	7.1
Aug. 18, 1959 (Aftershock)	West Yellowstone-Hegben Lake	VI	6.5
Aug. 18, 1959 (Aftershock)	West Yellowstone-Hegben Lake	VI	6.0
Aug. 18, 1959	West Yellowstone-Hegben Lake	VI	6.5
Mar. 28, 1975	Pocatello Valley, ID	VIII	6.1
June 30, 1975	Yellowstone National Park	VIII	6.4
Oct. 28, 1983	Borah Peak, ID	VII est.	7.3

CALIFORNIA AND WESTERN NEVADA REGION

The highest rates of seismic energy release in the United States, exclusive of Alaska, occur in California and western Nevada. The coastal areas of California are part of the active plate boundary between the Pacific and North American tectonic plates. Seismicity can be correlated with the well-known San Andreas fault system as well as many other active fault systems. A number of major earthquakes have occurred in this region; the most recent ones were the 1989 Loma Prieta and the 1992 Landers-Big Bear earthquakes. The following generalizations can be made: the earthquakes are nearly all shallow, usually less than 15 km (9 miles) in depth, the recurrence rate for a large (M_s greater than 7.8) earthquake on the San Andreas fault system is of the order of 100 years, the recurrence rates for large earthquakes on single fault segments in the Nevada seismic zone are believed to be in the order of thousands of years, and almost all of the major earthquakes have produced surface faulting.

Important Earthquakes of California and Western Nevada

Date	Location	Maximum MMI (I_o)	Magnitude (Approx. M_s)
Dec. 21, 1812	Santa Barbara Channel	X	
June 10, 1836	Hayward fault, east of San Francisco Bay	IX-X	
June 1838	San Andreas fault	X	
Jan. 9, 1857	San Andreas fault, near Fort Tejon	X-XI	
Oct. 21, 1868	Hayward Fault, east of San Francisco Bay	IX-X	
Mar. 26, 1872	Owens Valley	X-XI	
Apr. 19, 1892	Vacaville, CA	IX	
Apr. 15, 1899	Mendocino County, CA	VIII-IX	
Dec. 25, 1899	San Jacinto, CA	IX	
Apr. 18, 1906	San Francisco, CA	XI	8.3
Oct. 3, 1915	Pleasant Valley, NV	X	7.7
Apr. 21, 1918	Riverside County, CA	IX	6.8
Mar. 10, 1922	Cholame Valley, CA	IX	6.5
Jan. 22, 1923	Off Cape Mendocino, CA	(IX)	7.3
June 29, 1925	Santa Barbara Channel	VIII-IX	6.5
Nov. 4, 1927	West of Point Arguello, CA	IX-X	7.3
Dec. 21, 1932	Cedar Mountain, NV	X	7.3
Mar. 11, 1933	Long Beach, CA	IX	6.3
May 19, 1940	Southeast of El Centro, CA	X	7.1
July 21, 1952	Kern County, CA	XI	7.7
July 6, 1954	East of Fallon, NV	IX	6.6
Aug. 24, 1954	East of Fallon, NV	IX	6.8
Dec. 16, 1954	Dixie Valley, NV (2 shocks)	X	7.3
Feb. 9, 1971	San Fernando, CA	XI	6.4
Oct. 15, 1979	Imperial Valley, CA	IX	6.6
May 2, 1983	Coalinga, CA	VIII	6.5
Oct. 1, 1987	Whittier Narrows, CA	VIII	6.1
Oct. 17, 1989	Loma Prieta, CA	VII	7.1
June 28, 1992	Landers, CA	VII	7.4
June 29, 1992	Big Bear, CA	VII	6.5
Jan. 17, 1994	Northridge, CA		6.6

WASHINGTON AND OREGON REGION

The Washington and Oregon region is characterized by a low to moderate level of seismicity in spite of the active volcanism of the Cascade range. With the exception of plate interaction between the North American and Pacific tectonic plates, there is no clear relationship between seismicity and geologic structure. From the list of important earthquakes that have occurred in the region, two of the three most recent damaging earthquakes in the Puget Sound area ($M_S = 6.5$ in 1965, $M_S = 7.1$ in 1949) occurred at a depth of 60 to 70 km. The third, the 1992 Petrolia earthquake ($M_S = 7.1$) occurred in the Mendocina triple junction where the Gorda, Pacific, and North American plates converge. Currently, speculation is occurring over whether a great earthquake can occur as a consequence of the interaction of these tectonic plates.

Important Earthquakes of Washington and Oregon

Date	Location	Maximum MMI (I_0)	Magnitude (Approx. M_S)
Dec. 14, 1872	Near Lake Chelan, WA (probably shallow depth of focus)	IX	(7.0)
Oct. 12, 1877	Cascade Mountains, OR	VIII	
Mar. 7, 1893	Umatilla, OR	VII	7.0
Mar. 17, 1904	About 60 km NW of Seattle	VII	
Jan. 11, 1909	North of Seattle, near Washington/British Columbia border	VII	(5.7)
Dec. 6, 1918	Vancouver Island, B.C.	(VIII)	(5.8)
Jan. 24, 1920	Straits of Georgia	(VII)	
July 16, 1936	Northern OR, near Freewater	VII	
Nov. 13, 1939	NW of Olympia	VII	6.3
Apr. 29, 1945	About 50 km SE of Seattle	VII	
Feb. 15, 1946	About 35 km NNE of Tacoma (depth of focus 40-60 km)	VII	7.2
June 23, 1946	Vancouver Island	(VIII)	7.1
Apr. 13, 1949	Between Olympia and Tacoma (depth of focus about 70 km)	VIII	
Apr. 29, 1965	Between Tacoma and Seattle (depth of focus about 59 km)	VIII	6.5
Apr. 25, 1992	Petrolia (depth of focus about 10 km)	VII	7.1

ALASKA REGION

The Alaska-Aleutian Island area is one of the most active seismic zones in the world. The Queen Charlotte Island-Fairweather fault system marks the active boundary in southeast Alaska where the Pacific plate slides past the North American plate. The entire coastal region of Alaska and the Aleutians have experienced extensive earthquake activity, even in the relatively short time period (85 years) for which the record of seismicity is well known. The most devastating earthquake in Alaska occurred on March 28, 1964, in the Prince William Sound. This earthquake, which has recently been assigned a moment magnitude of 9.2, also probably was the largest historical earthquake. It caused 114 deaths, principally as a result of the tsunami that followed the earthquake. The regional uplift and subsidence covered an area of more than 77,000 square miles.

Important Earthquakes of Alaska

Date	Location	Magnitude (Approx. M_s)
Sept. 4, 1899	Near Cape Yakatage	8.3
Sept. 10, 1899	Yakutat Bay	8.6
Oct. 9, 1900	Near Cape Yakatage	8.3
June 2, 1903	Shelikof Strait	8.3
Aug. 27, 1904	Near Rampart	8.3
Aug. 17, 1906	Near Amchitka Island	8.3
Mar. 7, 1929	Near Dutch Harbor	8.6
Nov. 10, 1938	East of Shumagin Islands	8.7
Aug. 22, 1949	Queen Charlotte Islands (Can.)	8.1
Mar. 9, 1957	Andreanof Islands	8.2
Mar. 28, 1964	Prince William Sound	8.4
Feb. 4, 1965	Rat Islands	7.8

HAWAIIAN ISLANDS REGION

The seismicity in the Hawaiian Islands is related to the well known volcanic activity and is primarily associated with the island of Hawaii. Although the seismicity has been recorded for only about 100 years, a number of important earthquakes have occurred since 1868.

Tsunamis from local as well as distant earthquakes have impacted the islands, some having wave heights of as much as 15 meters (55 feet).

Important Earthquakes Causing Significant Damage in Hawaii

Date	Location	Maximum MMI (I_0)	Magnitude (Approx. M_s)
Apr. 2, 1868	Near south coast of Hawaii	X	
Nov. 2, 1918	Mauna Loa, HI	VII	
Sept. 14, 1919	Kilauea, HI	VII	
Sept. 25, 1929	Kona, HI	VII	
Sept. 28, 1929	Hilo, HI	VII	
Oct. 5, 1929	Honualoa, HI	VII	6.5
Jan. 22, 1938	North of Maui	VIII	6.7
Sept. 25, 1941	Mauna Loa, HI	VII	6.0
Apr. 22, 1951	Kilauea, HI	VII	6.5
Aug. 21, 1951	Kona, HI	IX	6.9
Mar. 30, 1954	Near Kalapana, HI	VII	6.5
Mar. 27, 1955	Kilauea, HI	VII	
Apr. 26, 1973	Near northeast coast of Hawaii	VIII	6.3
Nov. 29, 1975	Near northeast coast of Hawaii	VIII	7.2
Nov. 16, 1983	Near Mauna Loa, HI		6.6

PUERTO RICO AND THE VIRGIN ISLANDS REGION

The seismicity in the Puerto Rico and Virgin Islands region is related to the interaction of the Caribbean and the North American tectonic plates. The Caribbean plate is believed to be nearly fixed while the North American plate is moving westward at the rate of about 2 cm/year. Earthquakes in this region are known to have caused damage as early as 1524-1528. During the past 120 years, major damaging earthquakes have occurred in 1867 and 1918; both earthquakes had tsunamis associated with them.

Important Earthquakes on or Near Puerto Rico

Date	Location	Maximum MMI (I_a)	Magnitude (Approx. M_s)
Apr. 20, 1824	St. Thomas, VI	(VII)	
Apr. 16, 1844	Probably north of PR	VII	
Nov. 28, 1846	Probably Mona Passage	VII	
Nov. 18, 1867	Virgin Islands (also tsunami)	VIII	
Mar. 17, 1868	Location uncertain	(VIII)	
Dec. 8, 1875	Near Arecibo, PR	VII	
Sept. 27, 1906	North of PR	VI-VII	
Apr. 24, 1916	Possibly Mona Passage	(VII)	
Oct. 11, 1918	Mona Passage (also tsunami)	VIII-IX	7.5